

Flexural Performance of Self Consolidating, Self Cured Concrete Beams -Incorporating Sap

Sanjay Raj. A, S.B. Annadini

Abstract: Self- Compacting Concrete (SCC) is a sort of Concrete that possesses high flowing, passing ability, which can be placed and compacted due to its own weight without any peripheral compaction effort, at the same time it is cohesive enough to be handled without any segregation or bleeding distinctiveness. This Research Study presents an experimental exploration Flexural behavior of Internal cured Self Compacting Concrete (ICSCC) with fine aggregate substitution by Crushed Rock Fines (CRF) at 0% & 30%, with silica fume as supplementary for cementitious material. Mix Proportions for ICSCC, controlled specimens SCC and Normal Conventional Concrete (NCC) M40 grade is arrived. For each concrete mixes 150mm X 150mm x150mm cubes and 100 X230 X 1500mm beams were casted and exposed to internal curing at ambient temperatures for 7 and 28 days. The results arrived for ICSCC mixes were paralleled with controlled specimens of SCC and NCC. Appropriate materials were selected to have a better performance to ensure efficient internal curing in the concrete mass. The Flow Properties of SCC, ICSCC mixes have been performed as per EFNARC Stds and results of flow properties were within limits. Analysis made from the experimental exploration is accomplished that the Flexural characteristics for ICSCC mixes carried at ambient temperature found acceptable.

Keywords: Self Curing, Silica Fume, Self-Compacting Concrete, Workability, Compressive Strength and Flexural Strength Characteristics.

I. INTRODUCTION

SCC is the present transforming category concrete, characterized by its ability to spread and self consolidate in the formwork exhibiting without any significant separation of constituents. Elimination of vibration for placing the SCC leads to substantial advantages related to better homogeneity. The replacement of cementitious materials from fly ash, silica fume increases the paste content and hence enhances the properties in fresh and hardened state of concrete.

The conventional curing methods are not so effective in preventing early cracking which is associated with self-desiccation and autogenous shrinkage [Bentz and Snyder 2009]. In View of these limitations, several internal curing strategies have been recently developed.

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The internal relative humidity remains high in internal cured concrete and the shrinkage resulting from self-desiccation is limited or avoided [Philleo et al 1999]. The purpose of this investigation is to study the effects of Super Absorbent Polymer [SAP] for internal curing on Mechanical characteristics and flexural behavior of beam specimens. The Experimental Program was designed to Study the Specified objectives.

(i) To assess the effectiveness of various percentages of mineral and chemical admixtures in producing SCC and ICSCC Mixes. (ii) Flowing characteristics depending on the precise proportioning of ingredients and dosage of super plasticizer/viscosity modifying agent. (iii) Compressive strength. (iv) Flexure behavior of beam specimens

II. MATERIALS USED

The percentage of all replacement materials have been worked out from the trial and error method. Natural sand was replaced by CRF by 0% and 30%, silica fume was added to cement. The super plasticizer (Glenium B233) high range water reducing admixtures and Viscosity modifying agent (VMA) have been used to enhance the flow properties. The SAP was used in a mix to ensure for internal curing of concrete.

Table1: Materials Used in Research Work

Cement	Ordinary Port land cement of 53 grade conforming to IS-12269 having specific gravity of 3.15
Fine Aggregate	Natural river sand conforming to IS-383, Zone –II having specific gravity of 2.7
Coarse aggregate	Crushed granite angular aggregate of size 12.5mm passing conforming to IS-383 having specific gravity 2.73
Mineral admixtures	Quarry dust conforming to IS-383, Zone –II having specific gravity of 2.8, and silica fume
Chemical admixtures	Master Glenium Sky B233 and SAP (curing agent)
Water	Ordinary potable water conforming to IS 456

III. EXPERIMENTAL PROGRAM

Experimental exploration was carried out in to two phases to investigate few parameters. In the first phase, M40 grade concrete mix was considered for the experimental investigation in which constant silica fume addition to cement and Natural sand is partially replaced with CRF by 0% and 30%. EFNARC guidelines have been referred to achieve the flow properties. The compressive strength of ICSCC mixes are compared with SCC and NCC controlled Mixes.

Flexural Performance of Self Consolidating, Self Cured Concrete Beams -Incorporating Sap

In the second phase, flexural behavior of Internal cured ICSCC Mix beam specimens have been compared with the specimens made out of Reinforced with SCC and NCC as controlled Mixes. All the mixes were prepared with w/c ratio of 0.45.

Table 2: Mix Proportions

Desig/ Materials	Ce me nt kg/ m ³	Silic a fum e kg/ m ³	FA kg/ m ³	CRF kg/ m ³	CA kg/ m ³	Wa ter	S P %	SA P %
NCC	384	0	906	0	990	172.8	0	0
NSCC 1	395	115	918	0	725	208	1	0
NSCC 2	395	115	918	0	725	208	1	0
ICSCC 1	395	115	917	0	725	208	1	0.1
ICSCC 2	395	115	917	0	725	208	1	0.2
ICSCC 3	395	115	917	0	725	208	1	0.3
ICSCC 4	395	115	642	275	725	208	1	0.1
ICSCC 5	395	115	642	275	725	208	1	0.2
ICSCC 6	395	115	642	275	725	208	1	0.3

3.1 Fresh Properties

The fine /total aggregate ratio 0.55 as per Nan-Su method of mix design and paste volume 50% for the Slump requirements was considered. The Volumetric proportions of the mixes are tabulated in Table 2. The individual volume fraction of the additional amount for internal curing of SAP mixes, which is not part of the mix water was 0.025 (corresponding to amount of 25kg/m³). Superplasticiser (SP) dosage was same for all mixes.

The slump flow test is widely used in assessing concrete consistency. The flow properties flow ability, passing ability and filling ability have been evaluated using the Slump flow; U Box, L-Box, J-Ring, V-funnel and fill box tests by performing the respective test and equipment. From Experimental exploration it was observed that flow properties satisfying the EFNARC specification. The fresh properties of SCC are tabulated in Table 3.

3.2 Mechanical properties

Compressive strength of specimens: 150mm x 150mm x 150mm cubes were casted to evaluate the compressive strength of each mix as per IS516:1959 and performed the Test in compressive testing machine of 2000 kN capacity and results are tabulated in Table 5.

IV TEST PROCEDURE

4.1. Beam geometry and Reinforcement Configuration

Experimental exploration comprises of 9 beams specimens of cured for 28 days. M40 grade concrete was used for casting the beam specimens comprising 0.1% of reinforcement, signifying as Under Reinforced sections. Amongst the 9 beam specimens, 6 beam specimens are cast of concrete with silica fumes added CRF and SAP as Internal Curing agent and they are symbolically represented

as ICSCC1 to ICSCC6. Beam Specimens with silica fumes added CRF beams symbolized as SCC1, SCC2, NCC represented are controlled specimens as tabulated in Table 4, detailed as per IS13920. For Experimental Model, the dimensions of beam were 100mm X 230mm and beam length of 1800mm.

Table 3: Fresh Properties

Sl. No	Tests	0% Quarry dust with 100% fine aggregate	30% quarry dust with 70% fine aggregate	EFNARC STD
1	mp-Flow by Abram's cone	675mm	743mm	650-850mm
2	n Slump Flow	4sec	3sec	3-5 s
3	J-Ring	5mm	3mm	3-8mm
4	U-Box	25mm	20mm	30mm
5	L-Box	0.8	0.81	0.8-1
6	- Funnel	6sec	10sec	6-12
7	unnel @5min	8sec	11sec	6-12

Table 4: Details of Beam specimens tested at 28 days.

SL No	Design Consideration	Beam Notation	% Reinforcement	Reinforcement Provided
1	Under Reinforced Section	NCC	0.1%	2-16#, 2-12#
2		SCC 1	0.1%	2-16#, 2-12#
4		SCC 2	0.1%	2-16#, 2-12#
5		ICSCC 1	0.1%	2-16#, 2-12#
6	Under Reinforced Section	ICSCC 2	0.1%	2-16#, 2-12#
7		ICSCC 3	0.1%	2-16#, 2-12#
8		ICSCC 4	0.1%	2-16#, 2-12#
9		ICSCC 5	0.1%	2-16#, 2-12#
10		ICSCC 6	0.1%	2-16#, 2-12#

4.2.1 Normalization:

To comprehend the relative difference between collective target mean compressive strength of 48.25 N/mm² (i.e. strength of M40 grade concrete obtained as per mix design) and experimental obtained values tabulated in Table 5. Normalization of loads, deflections was carried out to understand and to account for possible changes in values of loads, deflections liable on the deviation of experimental value of compressive strength from expected value and are formulated as shown below.

Flexural Performance of Self Consolidating, Self Cured Concrete Beams -Incorporating Sap

Normalization of loads and deflections

Normalization for loads

$$\text{Normalization Factor} = \frac{\sqrt{f_{ck \text{ obtained}}}}{\sqrt{f_{ck \text{ expected}}}}$$

$$\text{Normalization} = \frac{\sqrt{f_{ck \text{ Exp}}}}{\sqrt{f_{ck}^1}} = \gamma_F$$

*For loads = P_{Exp} / γ_F

2. Normalization of deflection

$$\text{Normalization factor} = \frac{\sqrt{f_{ck \text{ expected}}}}{\sqrt{f_{ck \text{ obtained}}}} = \gamma_d$$

obtained

* For deflection = Δ_{exp} / γ_d

Table 5: Compressive strength of ICSCC, SCC and NCC Mixes

S L N o	Cubes Designat ion	Age of testi ng	Experime ntal Compress ive Strength in N/mm ² (ta rget mean strength)	Compressi ve Strength in N/mm ² (ta rget mean strength)	Normalizatio n Factors	
					Loa ds	Defle ctions
1	NCC	28	51.30	48.25	1.05	0.95
2	SCC 1	28	55.33	48.25	1.07	0.93
3	SCC 2	28	54.67	48.25	1.06	0.94
4	ICSCC	28	57.3	48.25	1.09	0.91
5	ICSCC 2	28	58.67	48.25	1.1	0.90
6	ICSCC 3	28	58.68	48.25	1.11	0.89
7	ICSCC 4	28	55.95	48.25	1.07	0.92
8	ICSCC 5	28	57.94	48.25	1.09	0.91
9	ICSCC 6	28	58.97	48.25	1.1	0.90

V. RESULTS AND DISCUSSIONS

5.1 Load V/S Deflection Behaviour

Deflection is one of the important serviceability in limit states to be satisfied in the design of concrete structures. IS: 456-2000 recommends a ratio of span to effective depth less than or equal to 20 as generally sufficient to restrict the deflections to an allowable value of span/250 or 20 mm, in case of simply supported beams.

Table 6 and Figure 3, 4, 6 reports the experimental and theoretical loads of the Reinforced ICSCC, controlled SCC and NCC Beams tested for 28 days curing period at ambient temperature. Based on the Experimental obtained values of deflections shown by ICSCC, SCC beams are less than that of NCC beams for different stages measured i.e. at cracking, service and ultimate loads., deflection of ICSCC beams are lesser by 31.6%, 36.7%, 26.8%, 43.7%, 34%, 31%, 39.5%, 37.23 and 32.2% in comparison to controlled specimens SCC and NCC beams respectively

For all ICSCC beams, first crack pattern appeared on an average switch at around 0.40 times of corresponding ultimate load in similar to SCC and NCC beams.

Table 6: Deflections of Silica Fumes added CRP Reinforced Concrete (ICSCC) Beam and Normal Reinforced Concrete Beam (NCC) for Under Reinforced Section.

S L N o	Beam Designation	Theoretical and Experimental Values						
		Pcr kN	Δcr mm	Ps kN	Δs mm	Pu kN	Δu mm	
1	SCC1	Expt	80	0.7	150	2.37	230	4.16
		Theot	20.6	0.4	71.8	1.36	97.3	1.84
2	SCC2	Expt	60	0.3	130	1.42	190	3.9
		Theot	20.6	0.4	71.8	1.36	97.3	1.84
3	NCC	Expt	50	0.8	110	2.29	160	3.8
		Theot	20.6	0.4	71.8	1.36	97.	1.84
4	ICSCC1	Expt	90	1.3	170	3.13	250	4.6
		Theot	20.6	0.4	71.8	1.36	97.3	1.84
5	ICSCC2	Expt	110	1.2	180	2.33	270	4.64
		Theot	20.6	0.4	71.8	1.36	97.3	1.84
6	ICSCC3	Expt	130	1.35	200	2.15	300	3.8
		Theot	20.56	0.43	71.8	1.36	97.3	1.84
7	ICSCC4	Expt	70	0.69	140	2.17	210	3.64
		Theot	20.56	0.43	71.8	1.36	97.3	1.84
8	ICSCC5	Expt	90	0.95	160	2.52	240	4.15
		Theot	20.56	0.43	71.8	1.36	97.2	1.84
9	ICSCC6	Expt	110	1.12	180	2.29	270	3.75
		Theot	20.56	0.43	71.8	1.36	97.2	1.84

Pcr – Cracking Load

Δcr – Deflection at Cracking

Load

Ps - Service Load

Δs – Deflection at Service Load

Pu – Ultimate Load

Δu – Deflection at Ultimate

Load



Fig 1: Schematic Representation for Testing of Beams

5.2 Ultimate Load

Table 6 and figure 2 reports experimental and theoretical ultimate loads of the beams tested. It was found that as the magnitude of SAP increases in the Reinforced ICSCC beams corresponding increase in the ultimate loads is detected.

Flexural Performance of Self Consolidating, Self Cured Concrete Beams -Incorporating Sap

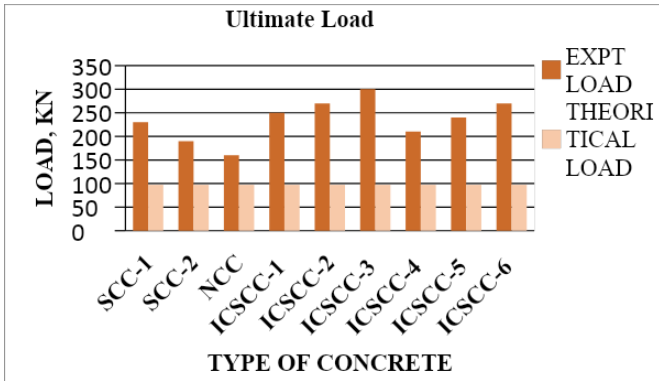


Fig 2: Ultimate load of ICSCC, SCC and NCC beams cured at 28 days

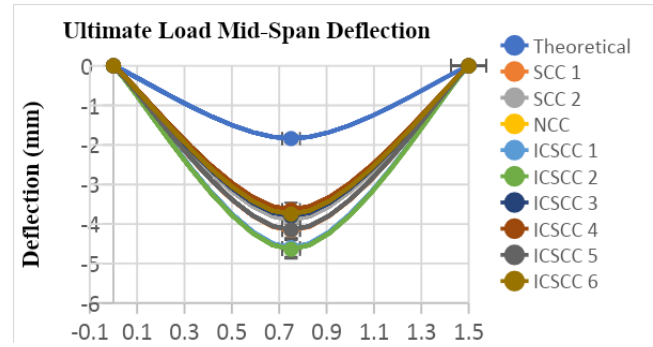


Fig 6: Load v/s mid span deflection behavior Reinforced ICSCC, SCC and NCC Beams at Ultimate Load

The experimental values of ultimate load are higher than those of theoretical values of ultimate load. The variation between experimental and theoretical ultimate load was similar between ICSCC and NCC beams, the ratio of experimental ultimate load to theoretical ultimate load varies on average 3.08 for ICSCC beam and 1.64 for NCC beams for different series cured at 28 days respectively.

5.4 Crack Spacing, Crack Width, Crack Pattern and Mode of Failure

Plain concrete is weak in tension, though it is a versatile and resilient in compression. It cracks at early stages of loading when the tensile strain is in the order of 0.0002 to 0.0005. In fact the tensile reinforcement becomes effective only when the concrete cracks, larger cracks are not acceptable, aesthetically not appreciable, promotes moisture ingress and effecting overall durability of structures. The ACI committee limits permissible values of cracking in structures for different exposure and environment conditions.

In the present investigation, thin cracks have been appeared at flexure tension zone, gradually extended upwards and widened as the load increased. It was observed in all the beams 2 to 3 very thin cracks appeared simultaneously during cracking load. The failure of beams in all cases was deemed to have occurred when the beams could not sustain any additional load. No crushing of concrete was observed in any ICSCC beams and Controlled specimen beams

The total number of cracks and number of cracks in tensile zone observed are tabulated in Table 7.

- The cracks are well distributed and symmetrical around the center. Few numbers of cracks that are found at shear span are inclined at 70° to 85° to the horizontal.
- Slightly wider cracks were observed in ICSCC beams than NCC beams of all series at both the age of Curing period. This is typically because of presence of CRP in ICSCC beams.

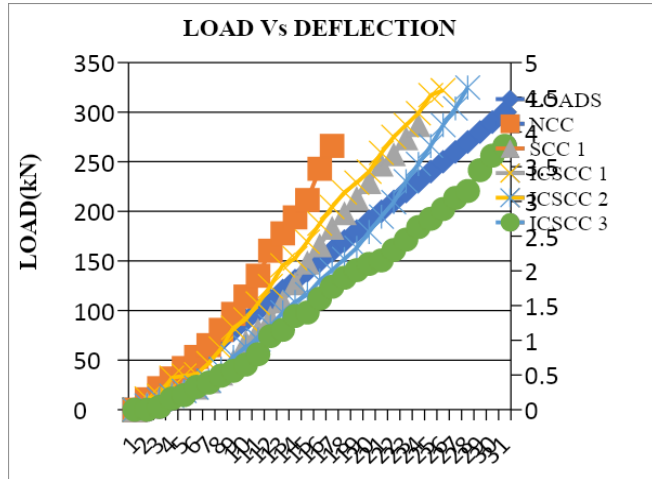


Fig 3: Load V/S Mid-Span Deflection for NCC, SCC 1 & ICSCC (0% Quarry Dust) Concrete Beams for 28 Days.

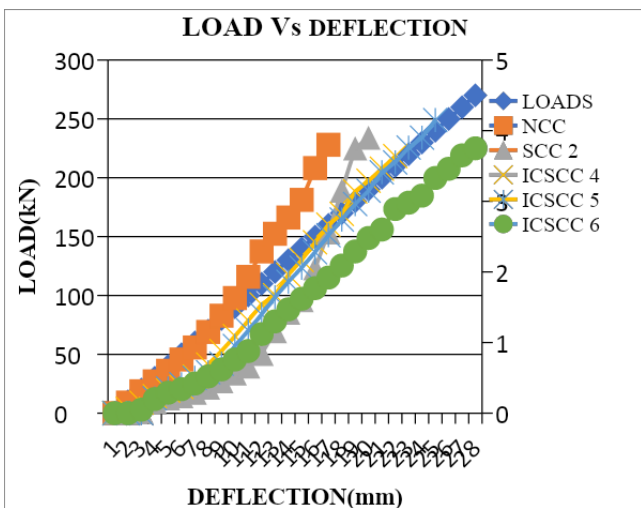


Fig 4: Load V/S Mid-Span Deflection for NCC, SCC 2 & ICSCC (30% Quarry Dust) Concrete Beams For 28 Days.



Fig 5: Casted ICSCC Beams



Fig 7 : Experimental Tested ICSSCC, SCC and NCC Beams

Table 7: Measured Spacing, Depth and width of Cracks in Different beam specimens cured at 28 days.

S I N O	Beam designa tion	No of flex ura l zon e cra cks	Crack Spacing mm			Crack Depth		Ma x wid th of cra cki ng (m m)	Mod e of failur e
			Min	Av g	Ma x	M in	Ma x		
1	NCC	12	49	93	13 6	35	205	0.9	Flexu ral
2	SCC-1	13	75	118	15 8	47	170	0.4	Flexu ral
3	SCC-2	13	58	104	14 8	40	180	0.3	Flexu ral
4	ICSCC -1	13	75	114	15 0	38	130	0.55	Flexu ral
5	ICSCC -2	12	96	137	17 7	45	150	0.45	Flexu ral
6	ICSCC -3	10	102	148	19 0	50	110	0.31	Flexu ral
7	ICSCC -4	14	62	108	15 0	60	160	0.7	Flexu ral
8	ICSCC -5	11	85	124	16 3	50	155	0.3	Flexu ral
9	ICSCC -6	9	97	140	17 9	40	195	0.1	Flexu ral

VI. CONCLUSION

Commencing the Experimental exploration results subsequent Conclusions are drawn.

- Inmost the parameters of mix proportions of ICSCC mixes having CRF as partial replacement for Natural river sand at various levels can be concluded that ICSCC mixes with good workability and improved flow properties both filling and passing ability were within prescribed limits as per EFNARC standards
- ISCCC Mixes internal cured at ambient temperature have identical flexural strength compared to SCC and NCC mix Specimens
- The strength accomplished at 28days varies between 0.9 to 1.2 times of strength characteristics for compressive strength intended for all types of ICSCC concrete mixes internally cured by using SAP at 0.1%, 0.2% and 0.3%
- From the research it is possible to initiate that SAP will be helpful to achieve curing internally at ambient temperature, i.e. water required for hydration of concrete which is not a part of mixing water conventional method.
- Self-curing will be the respond to numerous problems owing to be deficient in an appropriate curing. It can be applied to simple as well as in complex shapes

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REFERENCES

1. Basu.C.Prabir and Subrato Chowadry "Impact of Fine Aggregate Particle Size on Mortar Rehology for SCC", The Indian Concrete Journal Jan, pp. 7-14.
2. Hamid Rahimi and Allan Hutchinson. (2001), "Concrete Beams Strengthened With Externally Bonded FRP Plates", Vol. 5, No. 1.
3. EFNARC (2002), "The European Guidelines for SelfCompacting Concrete Specification, Production and Use.
4. Amit Mittal. Kaisare M.B. and Shetti .R.G. (2004). "Use of SCC in a pump house at TAPP 3 and 4". Tarapur the Indian concrete Journal. June, pp.32-34.
5. Bentz.D.P. & Synder (2009). "Protected paste Volume in concrete.Extension to internal curing". Concrete International, 27(2), 35-40.
6. Uysal, M. and Sumer, M. (2011). "Performance of self-compacting concrete containing different mineral admixtures." Construction and Building materials, Vol. 25, No. 11, pp. 4112-4120.
7. Geetha Kumari.T and Puttappa C.G. (2012), "Flexural Characteristics Of SFRSCC And SFRNC One Way Slabs", Volume 2, Issue 7.
8. Krishna Murthy.N, and Narasimha Rao A.V,(2012), "Mix Design Procedure for Self Compacting Concrete", Volume 2, Issue 9, PP 33-41.
9. Darole J. S. Prof. Kulkarni V.P (2013) "Effect of Hybrid Fiber on Mechanical Properties of Concrete", Volume 3, Issue 1.
10. Rashid Hameed and Alain Sellier, (2013), "Flexural Behaviour of Reinforced Fibrous Concrete Beams": Experiments and Analytical Modeling, Pak. J. Engg. & Appl. Sci. Vol. 13, July (p. 19-28).
11. Abibasheer Basheerudeen and Sivakumar Anandan. (2015), "Simplified Mix Design Procedures for Steel Fibre Reinforced Self Compacting Concrete", Volume 19 Issue 1

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